# ADDITIONAL NOTES ON GLACIATION IN THE KOSCIUSKO REGION

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*Synopsis*

This paper, complementary to those by the authors published in 1957 and 1963 respectively, is devoted chiefly to a description of signs of glaciation in the valleys of the Snowy and Indi systems during the second glaciation. Further evidence of an ice-cap glaciation is discussed, including the discovery of a glaciated rock-surface, and notes are given on the age of the glaciations.

## Introduction

In previous papers (Browne and Vallance, 1957, 1963)* we gave some account of Pleistocene glaciation of the Kosciusko plateau, devoting most attention to the first or ice-cap and the third or cirque stage and dealing only in general fashion with the evidences of the second or valley-glacier stage. In this paper we propose to deal with this last in somewhat greater detail. The features described we regard as essentially glacial, in places partially obscured by the effects of post-glacial processes but still recognizable. Most of them are shown on the topographic map in our 1957 paper.

Some parts of the area we have been able to examine fairly thoroughly; others, less accessible, have had less attention, and for a few we have relied partly on the evidence of air-photographs and of accurate contour-maps, for which we are greatly indebted to the Snowy Mts. Hydroelectric Authority. Mr. E. D. Gill very kindly placed at our disposal radiocarbon datings of peat-samples. We wish to make grateful acknowledgement of help in the field from geological colleagues, notably from Dr. G. H. Packham and Mr. (now Associate-Professor) A. S. Ritchie. One of us (W. R. B.) is under great obligation to his wife for discussion, references to literature, and transport and companionship in the field.

The general topography of the plateau has already been described (Browne, 1967). From Mt. Kosciusko the Main Divide of eastern Australia runs NNE, separating the waters of the Snowy system from those of the Indi (Upper Murray). The general altitude of the summit country varies from 7,000 feet A.S.L. in the vicinity of Mt. Kosciusko to 6,000 feet 23 miles to the north around Mt. Jagungal. To the south the Main Divide is submeridional, the country becomes lower, and some 11 miles south of Mt. Kosciusko there is a rather sudden drop of 700 feet from 5,300 feet A.S.L., due apparently to faulting. Possibly for a similar reason the surface drops rather rapidly north of Jagungal. Beyond these limits the evidences of glaciation are at best vestigial. The fall on the western side of the Main Divide is abrupt and of the order of 5,000 feet to the Indi, whereas on the east the Snowy is at most about 2,000 feet below the plateau surface.

## Glaciated Valleys

### *General*

In general the glaciers occupied valleys already carved by rivers and these were all to some extent modified by the passage of the ice, whilst many

* Hereinafter referred to only by the appropriate year.

acquired cirque-forms at their heads. The glaciated valleys were subjected to rejuvenation which, begun in late Pliocene, continued into late Pleistocene time; in some instances, in the high, steep country on the west it reached back almost to the Main Divide. Short descriptions of the physiography of most of the valleys have already been given (Browne, 1967).

Though glaciated valleys are numerous none of them have the vertical-sided cross-profile usually associated with many of the world's great glaciers, whose oversteepening is a function of the thickness of the ice they contain and its consequent high erosive power. Few of the Kosciusko glaciers probably exceeded 400 feet in thickness and the valleys that carried them have in general an open catenary or arcuate cross-profile, in some instances very perfect. A few valleys exhibit patches of glacially striated rock-pavement and some have *roches moutonnées* on their floors. Another characteristic is the presence of bedrock steps on the floor with risers of from perhaps 25 or 30 to about 250 feet and treads which are really very shallow, alluviated, swampy basins. Many of the valleys have one or more cirques in their courses or at the heads of tributaries hanging at varying heights above the floor of the trunk valley, their vertical rock-walls now converted to steep slopes (see 1963, p. 119). The steep profile at the cirque-head and immediately below it, followed by the very flat slope downstream, serves to distinguish the glacial *thalweg* from that of the normal stream-cut valley (Ray, 1949). Cross-moraines or stranded lateral moraines may be present, and in one instance a small thickness of glacial varved clays is revealed (Vallance, 1954).

Of the principal valleys those of the Snowy system show the most extensive and striking evidences of glaciation and receive most attention in these notes. The Crackenback except in its upper reaches was apparently not glaciated, though there are vestiges of small hanging glaciers in some of its tributaries. The whole of the Indi valley and most of that of its main tributary Geehi River were well below the lower limits of glaciation and for the most part the glaciers occupying the heads of their tributaries were small and short except in the north. On the other hand most of the glaciers in the Snowy tributaries appear to have joined the main Snowy glacier.

*Snowy River Valley*

The relatively flat-floored basin in which the Snowy River takes its rise lies east of the Etheridge Range at a little less than 6,400 feet, with walls rising to more than 7,000 feet A.S.L. on the west and 6,700 feet on the south and east, and is divisible into three sections. The most western, a swampy terrace forming the floor of a cirque-like depression south of Seaman Hut, is bounded east by a low rim of solid granite breached by two boulder-filled channels draining into the middle section, some 50 feet or more below, which contains the main Snowy; the surface of this rises gently east to a very low divide partly of solid granite, apparently ice-smoothed, and partly of moraine boulders, which leads to the slightly lower depression drained by Merritts Creek. The first and third sections are floored with unbanded clay, the middle section chiefly with coarse granite-sand. Large erratic boulders are abundant; among them acidic gneissic granites of Etheridge Range type are strewn all the way across the basin and include a few large blocks of silicified granite, one of them a roughly parallelepipedal mass 21 ft. × 21 ft. × 8 ft. It is uncertain whether the basin and its erratics are to be regarded as products of the ice-cap glaciation.

Immediately north of where the Summit road crosses Merritts Creek is the Masson moraine, between 150 and 200 feet thick and composed chiefly of granite boulders up to 20 feet long, including some of white gneissic granite. It appears to us that the moraine blocked the original Merritts

Creek, the headward part of which was diverted to join the Snowy. The beheaded trunk formed what is now the little Masson Creek heading in the moraine, which extends west to the Snowy with only a small outcrop of solid granite to mark the original watershed. Merging as it does into the widespread ground moraine it may be overlooked by the casual wayfarer, but from the valley of Masson Creek is plainly evident. The ice at the head of the Snowy may not have been much more than 300 feet thick.

Just upstream of the entry of Rawson Creek and Masson Creek the bed of the Snowy descends rather rapidly, dropping 300 feet in ½-mile. At the confluence of the streams a small, irregular rock-basin has been excavated, partly of glacial origin it would seem, since in Rawson Creek there are some *roches moutonnées* below the point where the gradient steepens. The valley of this creek must have carried a considerable volume of ice, and its glacier may have been up to 400 feet thick. About ¾-mile farther down the Snowy is another step of 150 feet, just upstream of the mouth of Club Lake Creek, and a little way above on the right bank is an almost level bank of pebbles and boulders already described (1957, p. 142). The base of this is only 5 feet above the present river-bed, and it seems to belong to the retreating phase of the valley-glaciation; in other words the present valley-floor is virtually that of the valley-glacier, which may here have been 400 feet thick so that the Mawson and Club cirques, with floors at about 6,400 feet A.S.L. (1963, p. 122) may have joined it with an ice-fall.

Below Club Lake Creek the Snowy River enters a wide-flared gorge, and its cross-profile is that of a glaciated valley with its floor notched by a rejuvenated stream (Browne, 1967, p. 128). A shoulder marks an older valley at 400 feet above the river, increasing to 500 feet below Blue Lake Creek. We interpret this shoulder as a remnant of the Snowy valley floor at the time of the ice-cap glaciation, perhaps coinciding approximately with a pre-glacial floor (Browne, 1967, p. 130). A thickness of more than 600 feet for the glacier in the gorge is indicated. On the right bank of the valley along the Summit road, and on the track from Charlottes Pass to the river, striated quartzite stones have been found up to 270 feet above river-level. Moreover, the ice must have overtopped Charlottes Pass (6,034 feet) and cascaded into Upper Spencers Creek valley (David, 1908, p. 664). We have already (1957, p. 138) noted the finding of striated quartzite stones on the steep eastern flank of Guthrie Range at 6,165 feet, and the western slope of this range is plentifully bestrewn, for 300 feet down from the col in the range (6,165 feet), with small stones of quartzite and less commonly of tinguaite of the type characteristic of the dyke in Blue Lake Creek across the Snowy. There is a dyke of tinguaite also in the col, of which large blocks strew the eastern slope of the range down to the Summit road, and appear in Lower Spencers Creek; some blocks of it lie between the col and the neighbouring peak of the range 200 feet higher than the outcrop. Striated quartzite stones as well as small tinguaite fragments are incorporated in the David moraine, and quartzite erratics are quite common along Trapyard Creek for at least ¾-mile up from its mouth and have been found in Betts Creek and Lower Spencers valley. It is clear, therefore, that diffluent ice from the Snowy glacier made its way into Upper Spencers valley over Charlottes Pass and the Guthrie Range col and that the main glacier overtopped the old valley-floor on the left bank of the Snowy. The quartzite and tinguaite stones, like the boulders of white granite that are found at intervals north to the Chalet cirque (1957), were apparently brought across the old Snowy valley by the ice-cap and later transported downstream by the Snowy glacier.

The quartzite erratics are of types characteristic of the metasedimentary belt that passes a little east of Mt. Kosciusko, and none has been found resembling the partially silicified slate inclusions occurring sporadically in the granite. The unaltered slate of the metasedimentary belt is too soft to survive even glacial transport, and the fragments occasionally found in borrow-pits along the Summit road are discarded pieces of road-metal brought from the former roadside quarries in Etheridge Range.

Just above its junction with Spencers Creek the Snowy River flows a little east of north, subparallel to the creek, and the Guthrie Range which separates them narrows and descends rather rapidly in two steps to 5,460 feet before ending in a steep slope 150 feet high descending to the river. The narrow promontory is evidently due to lateral abrasion by the glaciers in the two adjacent valleys and illustrates C. A. Cotton's observation that the ridges separating adjacent catenary troughs exhibit isosceles-triangular cross-profiles.

For the next 2 miles downstream to Guthega River the lower walls of the Snowy valley have a shorn appearance, the result of glacier passage. The glacial floor, which may have been about 40 feet or more above present river-level at the mouth of Spencers Creek, is 120 feet above it at Guthega River; below this point traces of what is thought to have been the glacier floor are to be seen for a few miles. The probable downstream limit of the glacier is discussed below.

### *Right-bank Snowy Tributaries*

*General.*—Almost all of these head in the Ramshead Range. Merritts Creek has already been mentioned. Masson Creek was apparently dismembered through ice-erosion (Browne *et al.*, 1956). Broadly speaking, the range has an undulating surface with altitude varying from 7,000 feet in the SW to less than 6,000 feet in the NE. It includes a number of shallow basins, of which that containing most of the Spencers Creek tributaries may be due to trough-faulting. From numerous flat cols creeks flow north to enter longitudinal tributaries of the Snowy.

It is considered that the range bears marks of the ice-cap glaciation and that the longitudinal valleys and most of their affluent valleys were later occupied by valley-glaciers.

*Spencers Creek.*—Of the valleys in Ramshead Range that converge to form Lower Spencers valley those of Upper Spencers Creek and its tributary Wrights Creek are perhaps the most interesting. The former, 1¼ mile long, is abnormally wide for its length and more than 800 feet deep with a very flat floor at 5,750 feet A.S.L. It heads in the composite Chalet cirque and at its lower end contains the David moraine, with a height of more than 100 feet and a summit-level of 5,845 feet.* Two small moraines cross the valley floor (David, 1908) and another at a comparable altitude (5,720 feet) mantles the David moraine. The glacier that occupied the valley must have been nourished by diffluent ice from the Snowy glacier coming over Charlottes Pass and the Guthrie Range col, and to a less extent by ice from the Chalet cirque and by the Wrights Creek glacier. There are conspicuous shoulders on the left bank of the valley at a little above 6,200 feet and at a corresponding height on the right bank of Lower Spencers valley where it is joined by Betts Creek; these are probably due to glacial erosion, for it is hard to explain the dimensions of the valley, its very level floor and the size of the David moraine without postulating some widening and overdeepening by a glacier not less than 500 feet thick.

We suggested (1957, 1963) that at least two phases of valley-glaciation are indicated by the phenomena in the Spencers Creek area. To the earlier,

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* The exposure of granite *in situ* not far down Lower Spencers valley at 5,720 feet casts doubt on the suggestion that the David moraine is 300 feet thick (Moye, 1955).

it would appear, belong the major features such as the larger deposits of moraine and certain higher-level remnants of what may have been glaciated valley-floors. The ice may have covered most of the drainage-area, and may even have spilled south over cols into the Crackenback valley. In this connexion it is probably significant that the David moraine is virtually continuous with deposits along the left bank of Upper Spencers valley and the left bank of Lower Spencers valley, and that in other valleys of the system there are accumulations at comparable heights some of which appear to be remnants of stranded lateral moraine. A later and much less intense glaciation may have been responsible for removing most of the older moraine material and depositing the lower moraines in Upper Spencers and Trapyard creek valleys, for example. The hypothesis of a two-phase valley-glaciation we have not tested by observations elsewhere than in the Spencers Creek basin.

The valley of Wrights Creek has been briefly noted by us (1957). It heads in a shallow, swampy basin of 100 acres at 6,550 feet A.S.L., with walls 150 to 250 feet high and a boulder-covered terrace of solid rock around it at 90-100 feet above the floor, which possibly indicates an earlier period of ice-excavation. Cols in the rim may have provided passage for diffluent ice into the Chalet cirque, Merritts Creek valley and the Crackenback valley. The basin is partly closed by a low moraine, and a little way downstream the erratic-strewn valley drops 170 feet with a sloping hang, and a succeeding cirque-like stretch, evidently the site of a shallow lake, is partly barred downstream by a spread of moraine boulders 100 yards long. The stream now tumbles 250 feet into a short canyon-like post-glacial gorge in solid jointed granite before turning left to join Upper Spencers Creek. The lower part of the valley, like that above the bend, has a perfect, wide-catenary profile and its floor and sides are covered thickly with moraine boulders. From about 5,900 feet it has a sloping hang of 220 feet in what appears to be lateral moraine, into the valley of Upper Spencers Creek.

The tract of country between Trapyard Creek and Upper Betts Creek, bounded north by Lower Betts Creek, nowhere rises much above 6,200 feet A.S.L., and has a maximum relief of about 300 feet. From the top of the David moraine there is a fine view of all the valleys converging towards the head of Lower Spencers Creek. Their floors are swampy and very gently sloping and appear to bear the impress of the second phase of the valley-glaciation. Erratics half-buried in the boggy ground are strewn about promiscuously or concentrated in ill-defined cross-moraines. The col at the structural head of Trapyard Creek (5,900 feet) and that at the head of Johnnies Creek (5,835 feet) contain moraine material (20 feet thick in the latter col), which extends downstream for 300 or 400 yards and seems to be continued at about the same level at intervals along the valley walls.

Trapyard Creek on its left bank has two branches heading at *ca.* 6,200 feet in the high country and flowing over it in shallow gutters. There is much moraine scattered about, some of which may have been left behind by the ice-cap. The two branches join the main valley obliquely with sloping hangs of some 400 feet, filled with boulders; their time-relation to the valley-glaciation is not clear.

The small but important occurrence of varve-clays associated with erratic stones in Trapyard Creek at 5,740 feet A.S.L. (Vallance, 1954) is the only definite deposit of the kind known in the Kosciusko area. As the clays must have been brought into a proglacial lake from upstream they would seem to belong to the second or minor phase of the valley-glaciation rather than to the earlier phase when ice-movement may have been towards the south. Unlaminated micaceous clays have been noted in Upper Spencers valley and in the beds of Betts Creek and Johnnies Creek, and thinly-banded deposits of gritty sand and peaty material occur in Rock Creek and in a little drained lake ¾-mile SW of Mt. Kosciusko, but they are not true glacial varves.

A short, wide tributary of Upper Betts Creek which may be called *Wheatley Creek* drops from a wide col at 6,100 feet on the SE of Mt. Wheatley through about 250 feet in 600 yards before flattening out. Its upper part is completely choked with huge granite blocks up to 20 feet long; these thin out downstream but continue as a sloping boulder-terrace on the right bank, which is prolonged down the side of Upper Betts valley to the Summit road. In so short a valley such an accumulation of boulders could never have been produced by running water. Some of them may originally have tumbled down from the rather steep right bank, but it may be suggested that the original deposit was left by an almost stagnant tributary glacier, and partially removed during the second phase of the glaciation.

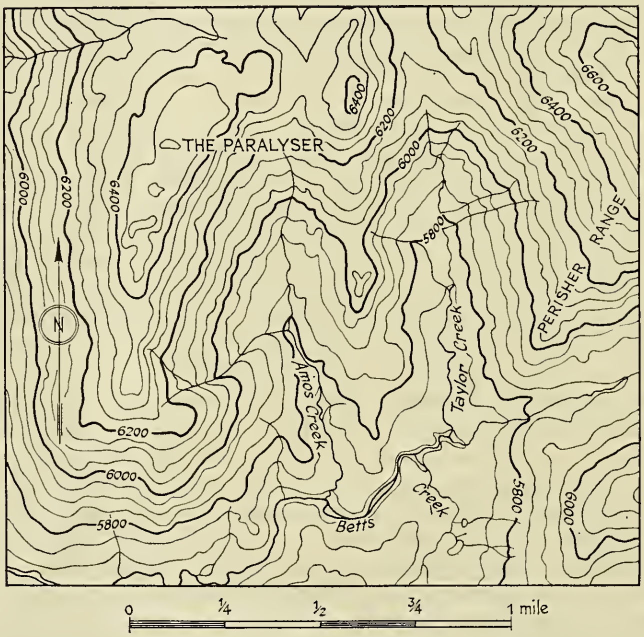


Fig. 1. Contour-map of the valleys of Amos Creek and Taylor Creek.

Lower Betts Creek valley has a roughly NE-to-SW direction and the creek meanders over a very flat flood-plain at a little over 5,700 feet. This extends also up the valleys of Upper Betts and Johnnies creeks and consists of the sediments of a former lake dammed by the low moraine at the head of Lower Spencers valley. Near the head on the flat floor is a low *roche moutonnée* with a fringe of moraine. The creek has three tributaries, one of which, Guthries Creek, occupies a wide, basin-like valley with numerous boulders, that drops on to the floor of Betts Creek with a hang of more than 90 feet, partly in solid rock, partly in moraine. West of this are two small valleys, each about a mile long, flowing south from the Perisher Range and heading in cols in which branches of the collinear north-flowing Farm Creek also head (Fig. 1). The two creeks, the more easterly of which may be called *Taylor Creek* after the late Prof. Griffith Taylor, the other being Amos Creek, occupy typical cirque-valleys, the latter about 550, the former nearly 400 feet deep. In both the original headslope has been subdued by weathering and erosion, and of the loose bouldery material in them it would be hard to say how much is lateral moraine. A train of boulders in one place may be due to recent slipping. The valley-head cols are 250 (Taylor) and 100 feet deep respectively, with cross-profiles that seem to have been smoothed, possibly by the passage of ice; their floors are partially eroded bogs strewn with boulders which are also piled up the sides to a height of about 70 feet in Taylor and 20 feet in Amos Creek col. They are typically rounded and massive, not slabby as one might expect if they were derived from the local rather sheared granite. On the almost flat floor of Taylor valley are two low recessional moraines behind which small temporary lakes were dammed; the floor of Amos valley is less sharply defined. Two small, flattish, southerly projections towards Betts Creek and at 100 feet above it may be remnants of the earlier Betts Creek glacier-floor dissected by the later glacier.

Lower Spencers Creek flows for 2 miles to the Snowy in a wide-flared valley with walls up to more than 800 feet high. It drops less than 50 feet in the first mile and thereafter a steepened gradient carries its floor down through 270 feet to its mouth. It is bordered, chiefly on its left bank, by a terrace of boulders, mainly of grey granite, rising almost to 5,800 feet A.S.L. and from 20 or 30 to about 200 yards wide, which continues to within ½ mile of the Snowy, where the Guthrie Range descends sharply to 5,750 feet. A few hundred yards down from the Summit road and some 20 feet or more above the creek an erratic boulder of white granite and a few striated quartzite stones were noted. Farther down, a few boulders of lamprophyre were found on the terrace, whilst many years ago David noted some blocks of tinguaite apparently derived from the Guthrie Range dyke. Some 100 yards down from the Summit road there is a small outcrop of rotten granite at 5,720 feet, perhaps 50 feet above the creek, and ¼-mile up from its mouth sheared granite appears *in situ* at 5,340 feet, but apart from those the valley-floor seems to be boulder-covered all the way down from the road, so that it is impossible to tell whether the boulder-terrace is a veneer or extends vertically down to creek-level. At all events it seems to be either a lateral moraine or part of a former glacial valley-filling which was partially removed in the second phase of the glaciation or by post-glacial river-erosion.

From the bridle-track leading down from Mt. Tate to the Snowy a splendid view is obtained of the valley of Trapyard Creek continued north as Lower Spencers valley, which descends from its head nearly 600 feet in 3½ miles to meet the Snowy. Spencers valley is seen to be about equal in size to that of the Snowy and it probably carried a glacier of comparable dimensions.

On the right bank of Lower Spencers valley a little flat-floored valley ¼-mile long with walls rising to more than 200 feet hangs 850 feet above the creek. Moraine material increases towards the mouth and a cross-moraine 20 feet high has dammed a little lake now drained. The valley may have been occupied by ice coming from the north-east over a low col and eventually cascading through perhaps 200 feet on to the top of Spencer glacier. On the left bank of Lower Spencers valley, on the slopes of the northern peak of Guthrie Range at about 6,200 feet A.S.L., are two small cirques which probably once contributed their modicum of ice to the main glacier.

*Farm Creek.*—The so-called Perisher Range, rising to 6,743 feet A.S.L., is traversed by a number of valleys, some draining directly to the Snowy, others entering Perisher Creek, the majority showing signs of having been glaciated.

The main Farm Creek valley is remarkably straight and is collinear with that of Guthega River across the Snowy. An eastern branch runs parallel to it for some distance and eventually turns sharply west to join it, collecting Blue Cow Creek at the bend. The main Farm Creek has two headwater branches rising in cols at more that 6,000 feet A.S.L. Immediately north of the cols the downstream slope is very gentle and boulders are scattered over the floors and sides of the shallow valleys. Across the main valley at 150 yards down from the col is a low moraine, and the flat floor downstream exposes the sediments of a drained lake; thereafter the creek steepens markedly and the western tributary comes in with a hang of 100 feet. The gradient becomes flatter again at *ca.* 5,900 feet and remains so for some 800 yards, thereafter increases markedly and in the mile to its mouth, now submerged in Guthega pondage, drops 600 feet with a concave slope.

The eastern branch of the creek, rising in a small col at 6,285 feet on the slope of The Perisher, quickly acquires a rather steep gradient which flattens out just above 5,900 feet, where the valley becomes U-shaped and swampy with numerous erratics on the floor and sides; thereafter it steepens to its junction with the more gently sloping Blue Cow Creek, and the combined stream eventually joins the western branch of Farm Creek in a rejuvenated valley. From the high Perisher Range on the east two main tributaries join the eastern branch. One of these rises at 6,320 feet in the 400-feet deep col between The Perisher and The Back Perisher; this is really the top of the sloping backwall of a perfect cirque whose floor, 200 yards in diameter, is *ca.* 150 feet below, with a well-marked lateral moraine on either side joined by a curving cross-moraine, forming the dam of a drained lake. A small secondary cirque is nested in the SW wall of the main cirque. The issuing moraine-strewn creek descends rather steeply to the flat floor of the main valley nearly 300 feet below, crossing in its course what may be two other recessional moraines. A low EW saddle opposite its mouth, in the ridge separating the two branches of Farm Creek, may have been made by ice in the eastern branch, augmented by that coming from the cirque, spilling over into the western branch of the valley 100 feet below.

The second tributary, Blue Cow Creek, issues from the swampy col immediately south of The Blue Cow and more than 400 feet below it. It is filled with boggy heath and erratics which continue down the valley. In the main valley and two left-bank tributaries cirque-hollows are seen at about 5,950 feet, which are virtually confluent and appear to be closed by breached moraine, and for some 600 yards above its junction with eastern Farm Creek valley the gently-sloping floor and catenary cross-section of the valley are suggestive of glaciation. As in many of the other creek-systems, Farm Creek and its tributaries have their beds heavily laden with boulders. Detailed interpretation of the topography is difficult, but clearly the valleys have been glaciated down to the 5,900-foot level and probably much lower.

*Perisher Creek.*—From Ramshead Range the drainage to Perisher Creek is by Rock Creek, which flows from a col at The Porcupines in a wide, shallow valley crossing a couple of low, sloping, bouldery terraces, the lower, at 6,100 feet, being continuous with the flat col at the head of Wheatley Creek. From this a minor tributary descends rapidly by steps and terraces in boulders and solid rock through more than 100 feet to meet the main Rock Creek, whose valley after descending 250 feet in ½-mile becomes somewhat asymmetrical and of distinctly mature aspect, particularly in its lower half. Halfway down it there is a sloping step of about 80 feet partly in solid rock into a wider, somewhat basin-shaped portion drained by the main creek and a short left-bank tributary; it is barred a few hundred yards up from the Summit road by a ridge of solid rock capped by boulders, which has caused alluviation and ponding and is breached by the present creek. Above the step moraine crosses the valley, and boulders are seen on the steep left bank for a few hundred feet up.

Upper Perisher valley heads in Perisher Gap (5,930 feet) and runs parallel to the Summit road. Very bouldery at its head, with occasional steps showing solid rock notched by the stream, it is crossed at 5,800 feet by what appears to be a moraine and at ¾-mile from the Gap is joined on the left by the creek draining Perisher cirque, a little below which is the eroded remnant of another cross-moraine. The valley, with a generally U-shaped cross-profile, now widens and a low lateral terrace of granite- and quartz-pebbles in a gritty matrix ends abruptly against the siltic flood-plain of the creek and rests downstream on a low, flattish *roche moutonnée* jutting from the left bank.

The so-called Perisher cirque is really a short, cirque-headed valley between The Perisher and The Back Perisher with a backwall sloping steeply up to the Perisher col at 6,320 feet, and a gently-sloping floor at 5,850–5,800 feet A.S.L., ending in a lip of solid granite topped with 10 or 15 feet of boulders and having a hang of 140 feet above the main valley.

A third component of the Perisher system rises at Pipers Gap and traverses the flat Perisher Plain. Some of the ice descending from the higher land to north and south may have spilt over into Pipers Creek valley, but most of it surmounted the low promontory on its right bank to join the Lower Perisher glacier.

After gathering in its main tributaries Perisher Creek turns north in a straight, wide valley up to 700 feet high on the west and showing a catenary cross-profile incised in the older valley to a depth of about 200 feet. The gradient is less than 50 feet to the mile and the floor appears to consist of three shallow basins separated by bars of solid granite and containing alluvium and peaty material, a sample of which gave an age of 8,100 ± 250 years B.P. Some 1½ miles down from the Summit road the valley-floor, crossed by a low moraine, drops through 300 feet in a sloping step and thereafter continues with an increased gradient, the valley narrowing at first and gradually widening again. Half-a-mile up from its mouth rejuvenation causes the creek to plunge over a waterfall into a little gorge.

To a greater extent than on the west the eastern side of the Perisher Range is cut into by cirque-like hollows related to the valley-glaciation. East of The Back Perisher are two of these, the more northerly heading in a flat col at 6,300 feet, the other starting at about 6,400 feet in the steep eastern face of the peak. The relatively steep gradient of the scoop-like valleys, roughened by what appear to be recessional moraines but may be rock-slides, flattens considerably at their convergence at 5,900 feet in a little dissected flat, probably the floor of a cirque-hollow. A sharp descent of more than 100 feet leads to the flat floor of the main cirque-valley, some 250 yards long, with a wide flare and a floor strewn with large granite boulders and an odd stone of lamprophyre. It is barred by a breached moraine 20 feet high on the edge of Middle Perisher valley and 60 or 70 feet above its floor. The walls of the cirque, like those of the Perisher cirque, are furrowed by small creeks. Farther north two creeks coming down from the plateau enter Perisher Creek at the base of the 300-foot step. The head of the more southerly is separated from the valleys just described by a prominent projection from the plateau at 6,300 feet with a general NE trend. The head of this creek makes a great arcuate recess not less than ¼-mile wide, and the valley-floor descends by a series of small steps in loose material to a lower step in boulders and solid rock at 5,660 feet; below that the valley drops steeply through 400 feet to Perisher Creek. The second creek issues from the deep Blue Cow col, below which the smooth, gentle slope of the arcuate U-shaped valley is cut into, forming a step with solid rock floor at 5,900 feet. Steps in boulder accumulations follow at intervals, and the creek drops precipitously in solid rock through 500 feet to Perisher Creek. The heads of both creeks were not improbably initiated by cirques and enlarged by sapping and nivation, and the steps in bouldery material are either cross-moraines or possibly the result of land-slides.

At the very head of the more southerly of the two valleys there is on either side a small cirquoid hollow 40 or 50 feet deep barred by a low ridge of boulders. Probably formed originally by land slides, they are being slowly enlarged by nivation.

The ice in Perisher valley above the 300-foot step must have been more than 200 feet thick. Immediately below the step, which marks the site of a considerable ice-fall, there are no clear signs of glaciation in the narrowed valley, but towards its mouth at 5,000 feet terraces on either side suggest a former continuation of the glacial floor some 600 feet above the present Snowy.

It is thought that the 300-foot step existed before glaciation and that ice in the cirque-headed, steep tributary valleys below it was hung well above the surface of the main glacier.

*Pipers Creek.*—The three tributaries of the longitudinal Middle Pipers Creek are Upper Pipers, Prussian and Wragges creeks. Of the first the well-defined part, about a mile long, starts at 5,800 feet, where the wide, bouldery stretch of the upper country begins to be definitely incised in the plateau with U-shaped cross-profile and a gentle gradient. The creek has cut through what seem to be moraine barriers, and one small tributary occupies a shallow cirque-headed valley. In addition to grey granite, boulders of white granite-gneiss, lamprophyre, microdiorite and vein-quartz are seen at intervals, but their provenance has not been investigated and some may well be of local derivation. Below 5,720 feet the gradient steepens markedly to the junction with Middle Pipers Creek at 5,450 feet.

Prussian Creek rising at just under 5,800 feet has a southerly trend for 500 yards in a wide, marshy valley, suggesting a former course to the Crackenback, but curves round to the north and narrows and steepens downstream.

Wragges Creek flows from a flat swampy col with scattered boulders at about 5,700 feet. Near its head the valley-floor slopes down to an elongated drained lake with moraine-boulders strewn across the valley below it. About 400 yards farther on is a second sloping step, and a small hanging valley enters from the right. Some 60 or 80 yards above the entry of a hanging right-bank tributary the valley becomes rejuvenated to its junction with Pipers Creek at 5,150 feet, though at its mouth are relics of the glacial floor 100 feet higher.

Thompsons Plain is an irregularly shaped, shallow basin structure on the top of Ramshead Range at *ca.* 5,800 feet, with walls rising more than 100 feet and a rather swampy, erratic-strewn floor showing occasional low granite outcrops. David (1908) confirmed Helms' opinion that the granite had been smoothed by glacial abrasion. There are two breaches in the rim on the NW and SE respectively, the latter, a little above the general level and containing erratics, evidently an old outlet to the Crackenback valley, the former leading into a tributary of Wragges Creek. This flows in a flat, grassy, boulder-floored valley gathering tributaries from right and left. Downstream the gradient steepens and the valley narrows and drops 200 feet in *ca.* ½-mile to the main Wragges valley.

The middle section of Pipers Creek begins at Pipers Gap in a hollow some 250 feet deep and partly filled with boulders, which may be a partly buried cirque, into which upper Pipers Creek empties from the right and Smiggin Holes from the left. This latter, now much modified and disfigured by man-made "improvements", was once a cirque-hollow some 200 feet deep, with a floor perhaps 200 yards in diameter, hanging 100 feet above Pipers

Creek. The longitudinal Middle Pipers valley shows some signs of having been glaciated. The upper parts of the bounding walls have a gentle slope which steepens abruptly at lower levels to give the appearance of faceted spurs, and the valley is crossed by two low moraines, the lower at 5,240 feet, below which signs of rejuvenation appear. On the left bank down from Smiggin Holes is a kind of moraine terrace perhaps 40 feet thick. The ice in the valley may have been as much as 200 feet thick.

At the point where the creek turns sharply to the left it is joined by the collinear Daners Creek, rising in a boulder-strewn col more than 250 feet deep ½-mile NNW of Daners Gap. The valley has a bowl-shaped head more than ¼-mile in diameter and extending over to Daners Gap, that gives the impression of having been filled with moraine boulders, later partly removed. Farther down the sides are boulder-strewn and the right bank is a truncated spur 300 feet high. Where the creek meets Pipers Creek the valley is barred by a little low ridge of massive granite surmounted by detritus, which may have formed a *riegel* against the passage of ice. In this the creek has cut a notch 40 feet deep and 40 yards wide, over which the water drops into a little rock-basin.

From the Summit road Lower Pipers Creek follows a WNW course in a very wide-flared valley with a low gradient, marked by boggy deposits. Some 1½ miles down a granite hill rises 100 feet above its floor, separated from a neighbouring hill by a saddle at 5,060 feet; this is filled to a depth of perhaps 40 feet with boulders predominantly of grey granite but including also some of vein-quartz and, significantly, a few of microdiorite such as has been observed *in situ* in the vicinity only at Daners Gap. The deposit, whose base is about 30 feet above the valley floor, may fairly be interpreted as a moraine; it continues WNW for about 300 yards across the col and down along a tributary valley which, a little farther on, has cut its way through a cross-moraine. The present Pipers Creek bears off to the north, descends about 75 feet in 500 yards, then swings round sharply to the left to unite with the moraine-containing valley. Post-glacial rejuvenation begins here and continues for 1¾ miles to the Snowy. The rejuvenated valley is deeply incised in the wide, flat-floored and obviously glaciated valley at about 4,950 feet. Near the mouth at 4,850 feet, 550 feet above the Snowy, is a little remnant of a sloping terrace which is probably part of the glacial valley-floor.

Where the main creek turns left its valley expands on the right into a wide basin formed by the convergence of two cirquoid hollows with floors at 5,000 feet A.S.L. The larger has been excavated to a depth of more than 300 feet, and though erratics are few on its sides and absent on its floor it was evidently occupied by ice; the smaller hollow is about 150 feet deep. Both have flat cols on their northern rims at 5,150 feet over which diffluent ice may have moved towards the Snowy glacier.

It would appear that during the glaciation the ice in part went over the moraine-bearing col and in part followed the present course of the valley, which became the preferred course of the post-glacial stream. Above the point of parting low terraces of moraine material and finer detritus may be traced upstream for more than ½-mile on the right bank of the valley at altitudes of 5,060 and 5,000 feet, and traces of erosion-terraces at about the same heights are visible on the left bank; they may be lake-shore phenomena due to temporary blockages downstream during glacial or post-glacial time.

On the right bank, one mile down from the road, is an elongated cirque near the lower end of a valley heading in the flat col of The Plains of Heaven (5,650 feet). From its head this valley gradually steepens downstream and at *ca.* 5,400 feet A.S.L. drops rather abruptly 100 feet into the hollow of the cirque which is 400 yards long, with partly boggy sloping floor and scattered erratics that concentrate downstream to form a cross-moraine and a kind of terrace behind a rock-bar. The walls of the cirque come down rather steeply with flat or concave slopes suggestive of glacial truncation. A notch 20 yards wide and 30 feet deep in the rock-bar may have been cut by the post-glacial creek, which, from this point, drops 300 feet in the next half-mile to join Pipers Creek.

Another cirque is seen on the left bank of the valley ½-mile down from the road. It has a floor about 250 yards in diameter and a backwall on the SW more than 200 feet high. The walls are dissected by a number of small creeks and the floor at *ca.* 5,170 feet hangs 100 feet and more above the valley-floor.

On the right of the road from Smiggin Holes to Perisher valley, just above where it enters the latter, is a cross-valley trending a little N of E from a col at 5,460 feet and more than 350 feet deep on the watershed between Perisher and Pipers creeks. The valley, ¾-mile long and tending to a bowl-shape downstream, bears marks of glaciation. About ¼-mile down from its head and below a moraine that once dammed a tarn there is an abrupt step of 50 feet in solid rock and the valley rapidly widens with a flat gradient, then tumbles over a waterfall of 50 or 60 feet into a somewhat youthful-looking creek flowing north to enter Pipers creek near the head of rejuvenation. This creek rises at 5,700 feet in the ridge at the back of Smiggin Holes cirque in a number of converging little tributaries, making an irregular hollow of roughly arcuate and cirquoid appearance. We have not explored the area in detail, but it appears not unlikely that there has been some glaciation in it followed by rejuvenation.

*Diggers Creek.*—The upper part of the basin of this creek is drained to the north by the main Diggers Creek rising a little north of Pretty Point, with Little Diggers Creek on the east and on the west an unnamed tributary bordering the Summit road. We believe that the valleys down to about 4,900 feet A.S.L. have been filled with ice, but it is not certain exactly to what extent they have been modified by subsequent river-erosion.

Diggers Creek heads in a number of flat, boggy cols in Ramshead Range at between 5,600 and 5,800 feet A.S.L. The headwater tributaries occupy valleys that are shallow and basin-like, grass-covered and boulder-strewn. Downstream they narrow and steepen abruptly, their rock-walled courses choked with boulders, and at about 5,400 feet they flatten out and converge to form the main valley. For more than ½-mile this is wide, flat and alluviated, but at 5,280 feet it drops rather abruptly in solid rock to form a narrow gorge and so continues for another ½-mile before flattening out again at 5,050 feet.

The western tributary rising ¼-mile south of Daners Gap is swampy, boulder-strewn and of low gradient at its head; at 5,500 feet it steepens, flattens out for a short distance and descends again rapidly in sympathy with the main creek, the watershed between them declining sharply as they converge. Their union at 5,000 feet occurs on the gently undulating floor of the main valley, which stretches NE for more than ½-mile to the artificial lake in front of the old hotel. This valley gives the impression of a glacial valley with two cirque-heads at 5,500 feet.

Many years ago the floor of the main valley was made into a golf-course, and doubtless in the process of sophistication asperities were removed; this may be the reason why, apart from odd boulders, the floor of the trunk valley shows no distinct signs of moraines.

Rising at 5,600 feet in a boggy flat ½-mile west of Andrews Lookout, Little Diggers Creek has a very flat, rather asymmetrical valley for its first ½-mile. From 5,500 feet its gradient increases in solid rock, which seems to have set a barrier athwart the shallow valley, and descends 100 feet in 300 yards, thereafter flowing over a wide plain just south of Alpine View and becoming increasingly cluttered with erratics of granite, vein-quartz and porphyrite. At 5,320 feet it turns left to begin a steep descent. Semi-circular in plan at the top, with smooth subvertical walls of massive granite $\frac{1}{4}$-mile apart, the valley narrows downwards with much congestion of angular and rounded boulders. At a little under 5,000 feet it reaches the floor of Diggers Creek in a fan of boulders and silty alluvium.

The valley traversed between Rennix Gap and the old hotel by the Summit road is wide, flat in cross-profile and rather boggy with occasional granite boulders or "floaters". Not far above the artificial lake the road used to curve around a small *roche moutonnée* of coarse-invaded by medium-grained granite, but this was obliterated during the widening and re-siting of the road. Like a number of other cols, e.g. Perisher Gap, Rennix Gap shows col-in-col structure and has a little median hump of solid granite.

The head of rejuvenation of Diggers Creek is immediately below the site of the old hotel (the hillock *ca.* 70 feet high on wich the hotel was built may have been another *roche moutonnée*), but down-valley it would seem that the cross-profile of the glacial valley continues for at least another mile.

*Left-bank Snowy Tributaries*

*Rawson Creek.*—The valley of Rawson Creek rising at Rawson Pass (6,960 feet) bears, particularly in its lower course, clear marks of glacial modification such as the Townsend moraine at Moraine (Townsend) Pass (apparently part of a former cross-moraine behind which a lake was formed), its characteristic cross-profile, the *roches moutonnées* on its floor, some in metasedimentary rock and the others in granite, the glacial striations (David *et al.,* 1901), the lateral moraine up to 100 feet above the floor, and the cross-moraine at the constriction where granite invades phyllite and the latter has been hollowed out into a basin. It is of interest that for more than $1\frac{1}{2}$ miles above their junction the valley of this creek is at a lower level than that of the main Snowy, partly, no doubt, because the latter is cut entirely in granite, but possibly also because the former carried the greater volume of ice.

*Club Lake and Blue Lake Creeks.*—As suggested above, only a small part of Club Lake Creek valley existed during the valley-glaciation, the lower part of it having come into being after the disappearance of the Snowy glacier; the same is true of the valleys of Carruthers Creek and Blue Lake Creek (1963, p. 125).

*Pounds Creek.*—The principal tributary of Pounds Creek, heading near Manns Bluff, together with part of the trunk valley, may have been determined by the existence of an old shear-zone trending a little east of north. They form a great erosional trough 800 to more than 1,000 feet deep between the Main Divide (rising to 7,200 feet at Mt. Twynam) and Crummer Range on the west and East Tate Ridge, a meridional spur thrusting south from Mt. Tate. The *thalweg* of the main valley, emerging from Twynam Cirque, drops 900 feet in $1\frac{1}{2}$ miles by a series of great steps (Fig. 2). At one place the creek seems to have been ponded behind a hard rock-bar or *riegel* before descending steeply to meet the Manns Bluff tributary, which is also stepped. The two unite to form a deep flat-floored trunk valley with occasional swampy patches, probably the remnant of the floor of a glacial valley. Downstream, at 5,400 feet, the stream is rejuvenated at 150 feet above the Snowy River.

Most of the tributaries enter from the west and some at least head in cirques. One of these, on the SE slope of Mt. Anderson with a headwall of about 200 feet, is breached by a wide col, which may have formed a diffluence channel to a glacier at the head of Watsons Gorge, a tributary of the Geehi.

It is not known whether the stepped sections of the two main valleys were glaciated all the way down to their junction. Some of the treads may be dissected cirque-floors, and the risers bear the marks of rejuvenation. They may be examples of the "giant stairways" so characteristic of mountain glaciations.

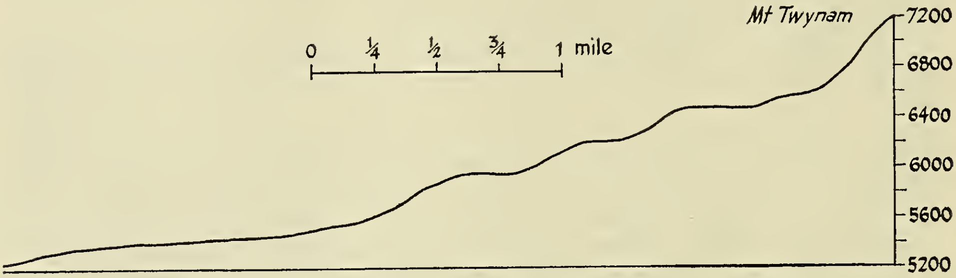


Fig. 2. Long-profile of the stepped main valley of Pounds Creek.

*Guthega River.*—As the result of arduous exploratory work in very difficult country some glacial features of the Guthega, Munyang and Finns River valleys were reported on by Ritchie (1953). Guthega River, collinear with Windy Creek, is separated from it by Consett Stephen Pass, a saddle upwards of 300 feet deep with a conspicuous hump of solid granite in the middle. The valley, whose head may be a modified cirque, for most of its length has a V-shaped cross-profile and a cascaded course, doubtless resulting from post-glacial rejuvenation. What we interpret as vestiges of the glacial floor at its mouth are some 120 feet above the bed of the Snowy, and shorn spurs appear on its right bank.

Owing to the relatively rapid descent of the Snowy between Guthega and Munyang rivers (Browne, 1967) the glacial floors of its tributaries downstream of Guthega River have been much dissected by rejuvenation and their relics now hang high above the present river.

*Munyang River.*—With its many tributaries this river drains a considerable area. The great flat-topped Whites River moraine near its head, derived mainly from the group of cirques on the right bank, stretches across the wide valley at 5,600 feet with a drained lake behind it, and extends downstream through a vertical distance of 270 feet, though its actual thickness is probably much less. The Main Divide here is at 6,300–6,400 feet A.S.L., and cirque hollows are arranged on steps or terraces at various levels up to 6,050 and 6,200 feet with considerable moraine material about them. The col at the head of the river, Schlink Pass, more than 850 feet deep, is also strewn with erratics, as is the slope down from it, with at least one breached cross-moraine about halfway. The left bank of the valley near its head is very different from the right, having no cirques in it but four little valleys scoring the steep scarp of Disappointment Spur and hanging more than 600 feet above the valley-floor.

The main valley and its tributaries have suffered considerable post-glacial dissection and only scattered remnants of what is thought to have been the glacial *thalweg* are to be seen on either side of the river. Ritchie has noted a number of cirque-headed tributary valleys, with some small moraines, on the western side and these have been left hanging well above the present valley-floor, whilst the river where it joins the Snowy at 4,350 feet is more than 500 feet below the remnants of the old glacier floor.

*Finns River.*—This rises on the Main Divide in a shallow col separating it from a collinear branch of Valentine River. Its head may be a cirque with reduced wall-slopes, and Ritchie found right-bank tributaries issuing from cirques with floors at between 6,000 and 6,400 feet, some of them on the slopes of Gungartan. These may be as much as 800 feet above the wide, flat floor of the present valley, which probably coincides approximately with the glacial floor, and during the glaciation the hang of the cirque-glaciers may have been of the order of 400 feet.

The main valley, deeply sunk into the plateau, continues for $1\frac{1}{2}$ miles with a drop of only 50 feet, but thereafter descends in a tortuous course through 600 feet in $1\frac{1}{2}$ miles to 4,950 feet, at which it expands into a swampy basin-like depression, thought to be glacial, whence it drops 950 feet to meet the Snowy.

Farm Creek, the principal tributary, emerges from what appears to be a shallow cirque at 6,000 feet, flows with a gentle gradient in a shallow U-shaped valley for $\frac{1}{2}$-mile, drops 200 feet in $\frac{1}{4}$-mile, resumes its gentle gradient and after receiving a tributary in a small cirque-headed valley, drops again rather quickly into a basin-shaped hollow at 5,100 feet to join the main river. Ritchie reported the presence of cross-moraines in the main valley and in that of Farm Creek.

*Tolbar Creek.*—Youthful for most of its length, this has one small tributary perched 600 feet above the present valley-floor and there are other relatively flat-floored depressions high above it which may be of glacial origin.

*Burrungubugge River.*—About 25 years ago part of the country west of this river near its head was briefly explored (Browne *et al.*, 1944) and certain glacial features noted. Some of its tributaries occupy what seem to be glaciated cirque-headed valleys, such as the wide, swampy, boulder-strewn valley descending from Brassy Gap and that of Dead Horse Creek with its tributaries, Macdonalds Creek on its left bank and an unnamed tributary on its right bank occupying a cirquoid valley 250 feet deep and 100 feet above the floor of the main valley. The Burrungubugge valley itself may have been glaciated from its head to a point about $\frac{1}{2}$-mile downstream from the mouth of Dead Horse Creek at *ca.* 4,800 feet A.S.L. Below this the deep and remarkably straight Burrungubugge valley closes in and assumes an appearance of early maturity. Two miles down from Dead Horse Creek is a right-bank tributary, Gate Creek, whose upper part occupies a swampy cirque-valley *ca.* 250 feet deep at 5,560 feet perched 900 feet above the river.

*Gungarlin River.*—Of this river the Burrungubugge may really be regarded as a tributary. It has a number of affluents rising in the high plateau, the upper parts of which may have been glaciated. The only one of which we have any knowledge is Teddys Creek, which flows east from Brassy Gap, a col 300 feet deep at 5,360 feet. Its valley drops very steeply from the col (400 feet in 700 yards) before beginning to flatten out, choked with boulders but without any obvious glacial features. Some of the headwater tributaries of Bulls Peaks Creek may be glaciated, but for most of its length the floor of the main Gungarlin valley is well below the probable lower limit of glaciation.

### *Length of the Snowy Glacier*

As already pointed out (Browne, 1967), there is reason to believe that as far down as Charlottes Pass the valley-floor of the Snowy coincides closely with that of the Snowy glacier. For several miles downstream of that point the present valley is incised to an increasing extent in an older one indicated by remnants on the valley-walls. Moreover, for many of the tributaries the present floors correspond quite closely with those of the valley-glaciers except where the latter have suffered post-glacial dissection. When their levels are compared with those of the vestiges of higher valley-floors within the Snowy valley the probability is seen to be strong that the latter are remnants of the Snowy glacier *thalweg*. Thus, whereas at the mouth of Club Lake Creek the glacial floor is only a few feet above the Snowy, the difference in altitude at the mouth of Pipers Creek is of the order of 550 feet; here the Piper glacier floor is 4,850 feet A.S.L., at a point within 300 yards of the present Snowy and indeed in the wall of its gorge. At their point of junction the Snowy and Piper glaciers were evidently still mobile and capable of erosion; farther down the river post-glacial rejuvenation has been so great that no comparisons are possible. However, it may be confidently inferred that the Snowy glacier extended down as far as Pipers Creek—in other words that it was at least 14 miles long. By itself it would, no doubt, have become a rather feeble thing that could not have lasted the distance, but it was well nourished by lusty tributaries from both sides which countered the effects of ablation.

*Crackenback River Valley*

In the high country forming the south-west half of Crackenback plateau, rising to more than 6,000 feet A.S.L., a multitude of streams tributary to the Crackenback, Mowamba and Indi have their sources. The valleys of many are of late-mature aspect and have almost certainly been glaciated; indeed some of the main valleys and their tributaries are cirque-headed.

The Crackenback River rises in a wide, deep col at 5,700 feet and is collinear with Wombat Gully, a tributary of the Mowamba, into which, in all probability, diffluent ice moved across the col. The upper section of the valley, known as The Big Boggy, is wide, arcuate in plan, some 6 miles long, with walls rising to 700 feet and more above a flat treeless floor, and with a general east-to-west direction until near Dead Horse Gap it turns sharply to follow a north-east course as the main Crackenback valley.

The Big Boggy, 100 to 400 yards wide, seems to consist of a number of shallow, alluviated and partly swampy basins separated by sloping steps and has a very low gradient over most of its course, falling in one stretch only 50 feet in $1\frac{3}{4}$ miles. In the last $\frac{1}{2}$-mile before reaching the great bend near Dead Horse Gap the gradient steepens somewhat and the valley narrows and assumes an appearance of early maturity. The valley-walls are in general fairly steep and some of the tributaries are cirque-headed with a hang of 400 feet and more. What may be lateral moraine was observed on the southern bank some 200 feet above the floor, but the floor itself, where examined, is relatively free of moraine boulders. There may have been considerable diffluent overflow of ice to the south across a low col into the head of Jacobs River, a Snowy tributary and, three miles upstream, into the cirque-like head of Teatree Creek, a tributary of Jacobs River. At the big bend the bed of the stream is filled with boulders, but these may have been derived, in part at least, from the Ramshead Range.

How far, if at all, the glacier made its way down the main Crackenback valley we have not ascertained, but it was probably not very far; indeed the narrowing of The Big Boggy valley near Dead Horse Gap may be a result of the glacier having dwindled through ablation, though, on the other hand, its snout may have reached as far down as Friday Flat and the site of the present Thredbo Village.

There are signs that hanging glaciers occupied valleys of some of its tributaries on the right bank below Dead Horse Gap. Bullock Yard Creek and No. 2 Creek rise on the Crackenback plateau, the former having short affluents in cirque-headed valleys hanging as much as 200 feet, whilst the latter, with few tributaries, takes its rise in a col. Both valleys, U-shaped and swampy, are sunk more than 600 feet below the plateau surface and downstream at 5,400 feet—1,200 feet and more above the Crackenback—rapidly steepen, whilst their creeks take on the appearance of consequent tributaries. Even if allowance be made for possible effects of rejuvenation the glaciers occupying the valleys must have dissipated some hundreds of feet above the floor of the trunk valley. Friday Flat Creek, No. 1 Creek and Bull Creek, all rising on the plateau at approximately 6,000 feet, may also have carried hanging glaciers.

In several tributaries of the Crackenback which take their rise in Ramshead Range there are indications of glaciation. Some of these features may have been impressed during the valley-glaciation, but as this is by no means certain, it is more convenient to describe and discuss them all in a later section.

*Indi River Valley Tributaries*

Owing to the very great and rapid fall of the country from the Main Divide in the vicinity of Mt. Kosciusko to the Indi River the surface quickly reaches a level below the limit of probable glaciation, and indeed any vestiges of glaciation have been obliterated by post-glacial river-erosion. For 10 or 15 miles to the south and 20 miles to the north, where the Divide is farther from the Indi, signs of valley-glaciation are not wanting in the more elevated country.

Starting from the south we note that the first valley to show distinct marks of glacial activity is that of *Cascade Creek* (Figs. 3 and 4), the upper part of which resembles The Big Boggy in being widely arcuate in plan and having a floor that consists of a number of steps or alluviated swampy basins, with risers of solid rock and moraine up to more than 30 feet high. Its principal head is a col upwards of 600 feet deep at 5,225 feet A.S.L., which separates it from a tributary of Jacobs River and is partly in solid rock, partly in moraine; the latter extends down a little distance into the collinear valley, into which ice may have overflowed from the Cascade glacier.

Of the tributary valleys some at least are cirque-headed. The largest and most conspicuous is on the right or northern bank, just west of Jerusalem Hill and south-west of Purgatory Hill, both upwards of 5,950 feet A.S.L. The structure is really composite, consisting of a main cirque enlarged by having at least one little perched cirque on either side. The main floor, at *ca.* 5,330 feet, is 400 yards in diameter with a sloping hang of 300 feet into the main valley, and the walls are mantled with boulders and scored with precipitous little streams forming the cascades from which the creek takes its name. Between the bounding hills is a col at 5,550 feet, partly in moraine, leading into a tributary of Jacobs River; it was probably overridden by ice from the cirque. North-west of Purgatory Hill is another cirque-headed valley; the creek issuing from it at 5,400 feet drops steeply through 550 feet to join the main valley.

The old bridle-track from Dead Horse Gap to Cascade Hut passes over what appear to be swampy cirque-hollows and patches of moraine at the head of a steep valley, between 5,750 and 6,000 feet; they may be relics of small tributary glaciers, hanging high above Cascade Creek. On the south side of the valley the plateau surface is lower and glacial erosion has left but little impress, though a few tributaries, as for example that which rises in a swamp in the Brodies Camp col (5,100 feet), may have been glaciated. About 3½ miles down from its head at an altitude of 4,800 feet, the valley of Cascade Creek begins to be rejuvenated and the creek drops rapidly through more than 2,000 feet to join the Indi.

*Dead Horse Creek* flows from Dead Horse (Grogin) Gap (5,210 feet) and is a tributary of Leatherbarrel Creek. It has a shallow cirque-like head and a catenary cross-profile, and accumulations of boulders strew its flat floor. Some 2 or $2\frac{1}{2}$ miles down at about 4,850 feet, apparently at the head of rejuvenation, the valley assumes a youthful aspect.

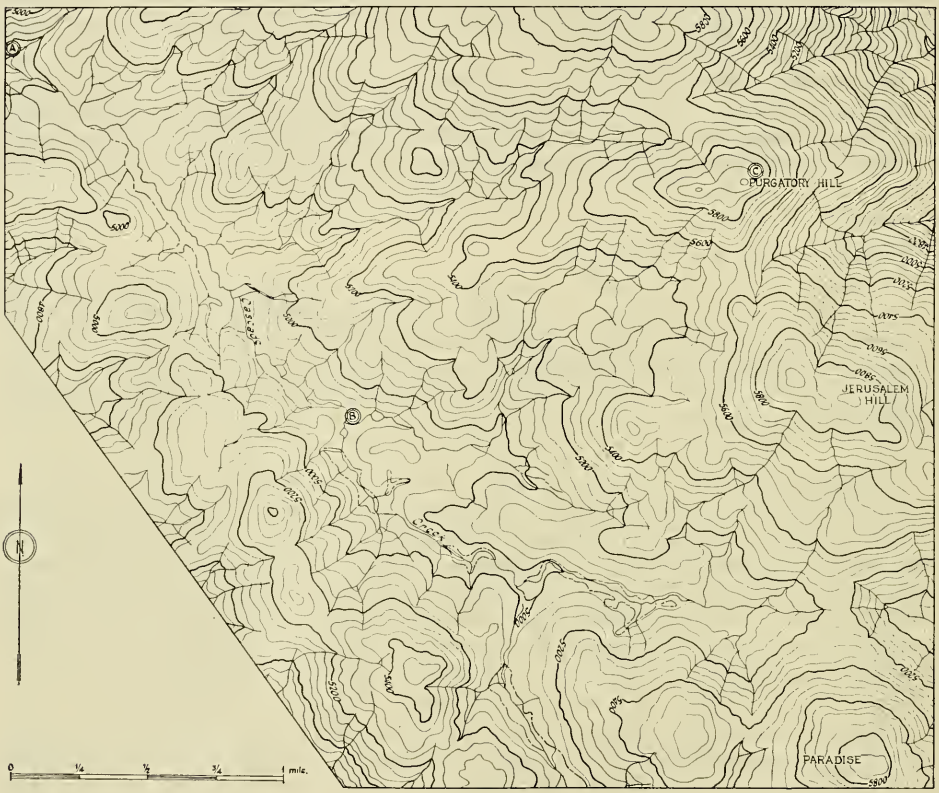


Fig. 3. Contour-map of the upper part of Cascade Creek basin. Alluviated swampy areas are indicated by broken lines.

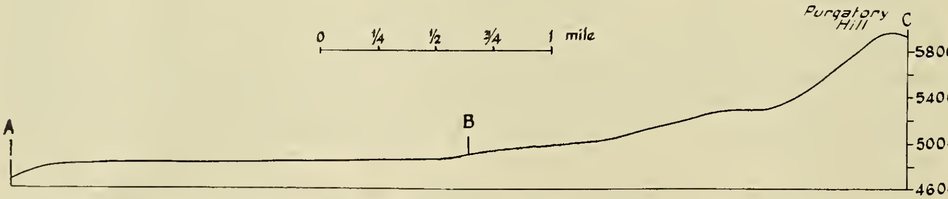


Fig. 4. Long-profile of Cascade Creek and its main cirque-headed tributary, along ABC on the map.

From the Rawson Pass col at 6,960 feet the valley of *Cootapatamba Creek* trends a little west of south for 2 miles to 6,200 feet, then the creek turns half-right through a low gap in the valley-wall to enter a bowl-shaped, roughly elliptical hollow whence it pursues a precipitous course to enter Geehi Creek (Brown *et al.*, 1956). Above the bend the valley has a catenary cross-profile with walls rising upwards of 800 feet above the floor, and has clearly been glaciated. Apart from the moraine which bars Lake Cootapatamba there are two others at lower levels which we interpret as recessional moraines of a valley-glacier. Farther down still, where the valley is in granite, at about $\frac{3}{4}$-mile below the lake at *ca.* 6,350 feet, there are 2 or 3 little steps up to 10 feet high in the floor which appear to be *roches moutonnées.* Below this the rock-floor of the valley has been buried under as much as 10 feet of coarse unstratified fluvial or fluvio-glacial *debris*—perhaps outwash gravels from a retreating glacier—in what may be an ice-gouged basin, for below, where the creek turns half-right, there appears to be a low rock-rim confining the alluvium. It has been suggested (Browne *et al.*, 1956) that at the time of the valley-glaciation Upper Cootapatamba valley continued down the collinear Leatherbarrel Creek; certainly remnants of the old glacial floor are to be seen as shoulders on the sides of the Leatherbarrel gorge for about $\frac{1}{2}$-mile, and the pattern of truncated spurs visible on the steep left bank of Cootapatamba Creek is repeated farther on in the Leatherbarrel valley.

Before entering the low defile Cootapatamba Creek receives a little misfit tributary from the north occupying a wide, open valley that slopes up more abruptly towards its head. It heads in a wide col at 6,455 feet A.S.L., bounded on the west by a short ridge 250 feet high and on the east by the southern continuation of the Kosciusko ridge; the granite walls on either side are smoothed. The col marks the watershed between Cootapatamba Creek and another more northerly tributary of Geehi Creek, which rises in a swampy lake, the head of a shallow valley cut in granite at 6,660 feet at the north-western foot of the Kosciusko ridge. The creek meanders south over its very flat valley-floor and $\frac{1}{4}$-mile down turns through a gap in its low west wall and drops 100 feet into a little alluviated basin where its banks expose a section of rhythmically banded granite gravel or grit and carbonaceous matter. This basin is bounded west by a granite ridge through which the creek passes in a little defile upwards of 150 feet deep at 6,400 feet A.S.L., the more gently sloping northern side of which is smoothed as if by the passage of ice. Once through this gap the creek plunges steeply into a great irregular hollow dropping some 950 feet in a mile before resuming its tortuous headlong course to meet Cootapatamba Creek.

The platform into which the shallow valley is cut may have been glaciated by the ice-cap, and the completely unorthodox behaviour of the creek in suddenly breaching its valley-wall and passing, farther down, through a higher wall athwart its course into a deep depression suggests glacial agency. The smoothing of the granite walls, the little *roche moutonnée* at the entrance to the defile, and the abundance of boulders clogging the streams, all point to the same cause. The deep basin itself, though much furrowed by little creeks, may once have been a glacial cirque, by now no longer clearly recognizable.

The platform under Mt. Kosciusko is drained to the north by another creek that hangs into Wilkinson Creek with a 250-foot drop.*

Passing north we note the great cirque-hollow that forms the source of *Wilkinson Creek.* Little needs to be added to our earlier description (1963) except the suggestion that on its eastern side Adams Pass (6,595 feet) may have been a channel for diffluent ice overflowing from the cirque into the valley of Rawson Creek. The small cirques on the steep south-western slopes of Abbott Range show no remnants of glaciated valleys and may belong to the third or cirque glaciation.

*Lady Northcote Canyon* has been rejuvenated back to the lip of Lake Albina, and its three principal tributaries, all on the right bank, were quite possibly glaciated in their headwater tracts, but if so all traces of glacial

* Previously (1957, p. 133) stated erroneously to be 500 feet.

activity have disappeared, though the great steep, acruate valley-heads give the impression of having been large cirques. The same applies to the chief tributary of *Watsons Gorge Creek,* and the main valley heading at 6,150 feet south of Mt. Anderson in a wide and deep col, very conspicuous from the high country across the Snowy, seems to retain traces of glaciation but rapidly deepens to a precipitous gorge. From the slopes of Mt. Anderson other Geehi River tributaries rise in well-defined cirquoid valleys heading north-north-west and north-north-east respectively with steep walls rising 400 feet and more above flat floors that, in a short space, give place to youthful gorges. The Main Divide from Carruthers Peak to Mt. Anderson, with Geehi tributaries heading on the north-north-west and Snowy tributaries on the east. presents the appearance of a scalloped upland.

*Windy Creek* valley is collinear with Guthega valley. Starting from Consett Stephen Pass (6,300 feet) it is remarkably straight for nearly 1½ miles, with steep walls that suggest ice-abrasion and a floor-step of 50 feet near the head, but on the whole with a gentle gradient. On the right bank are a number of hanging tributaries, some of which head in what appear to be shallow cirques. Ritchie (1952) reported breached moraines across the main valley and some of its tributaries. At 5,850 feet the glaciated floor begins to descend more rapidly through 400 feet, but resumes its gentle slope for 2 miles at a lower level. This part of the river sweeps round to the left in a great horseshoe bend with strongly asymmetrical cross-profile, the right bank rising 900 feet and more while the left bank does not exceed 300 feet. It is not certain if this section of the valley was glaciated, though at least one of its right-bank tributaries seems to have been occupied by a glacier near its head. The gently sloping valley terminates at 5,000 feet, where the river abruptly plunges down through 1,000 feet in ½-mile on its way to join the Geehi. A left-bank tributary of the rejuvenated stream bids fair to capture the gently graded section.

*Dicky Cooper Creek* occupies a north-directed valley heading in The Kerries at 6,250 feet but collinear with Munyang River by way of Schlink Pass, a col at 5,910 feet with a prominent median hump of solid granite. The valley, obviously glaciated, is wide, straight and flat, with alluviated, swampy floor and a few cirque-headed hanging tributaries coming from The Kerries ridge. At *ca.* 5,750 feet, about 1¼ miles down, it is crossed by a massive recessional moraine lying upon a *riegel* of solid granite that appears to mark the head of post-glacial rejuvenation, but after a relatively rapid descent of 200 feet over a narrow slate belt the winding valley widens and flattens for another mile before closing in again for its final descent to Geehi River.

Rising on the northern slope of Gungartan, *Valentine River* forms the eastern boundary of The Kerries ridge. Its head is in a little shallow cirque with a moraine damming a drained lake. Downstream the valley drops by a few low steps to assume a somewhat asymmetrical cross-profile, with wide flare and extremely gentle gradient, heavily alluviated and swampy. On its left bank are a few cirque-headed tributary valleys, the largest 600 yards long with floor at 6,300 feet, a backwall 100–150 feet high and a hang of 200 feet above the river. On the right bank a cirquoid valley joins the main valley opposite Mawson's Hut. Some 3½ miles from its head the main valley descends through about 100 feet and thereafter exhibits a symmetrical cross-profile and very low gradient for a mile to Mawson's Hut, below which it turns sharply left. It may have been glaciated for another 3 miles to the head of rejuvenation at 5,400 feet, ¾-mile from its junction with the Geehi. Observations made on the bridle-track from Mawson's Hut south-south-west to Dicky Cooper's Hut, supported by inspection of contour-maps, have shown that there are hanging cirque-headed valleys, at altitudes of 5,900 feet and more, tributary to the valleys of Valentine River and its affluent Duck Creek on the northern and western slopes of The Kerries; one in particular, with a backwall upwards of 400 feet high and a floor at 5,950 feet, hangs 400 feet above the Valentine valley.

Between Mawson's Hut and Mt. Jagungal there are a number of west-trending valleys which appear to be glaciated; this is particularly true of Rocky Plain River valley. It is also possible that the valleys of Back Flat Creek and Straight Creek and some of the headwater tracts of the Tooma and Tumut rivers have been modified by glaciers, but our acquaintance with this part of the plateau is slight, and, in any case, at the lower altitudes near the margin of the glaciated area the signs of glaciation are not so sharp and clear as at the higher elevations farther south.

## Ice-Cap Glaciation

Though it has been questioned more than once nothing that has been published undermines the validity of David's contention (1908), supported by us (1957, 1963), that the Kosciusko plateau experienced an ice-cap type of glaciation. The smooth profiles, so striking a feature of the topography at the higher altitudes, were evidently in existence before the valley-glaciation, as indicated by the sharp interruption of the convex surface of Northcote Peak and Carruthers Peak by the Mawson and Club cirques and of the southerly slopes of Northcote Peak and Mt. Clarke by the east-trending glaciated Rawson valley. Smoothing of the surface is not confined to the metasedimentary *terrain* but appears also quite extensively in the granite country, as on the eastern slope of Mt. Clarke and in many other places. Of course, weathering, erosion and soil-formation have modified the smoothed surfaces of both granite and metasedimentary rocks, but only to a relatively small extent.

The sharp contrast between the jagged, upstanding appearance of the isolated granite eminence of Mt. Etheridge, which David tentatively regarded as a *nunatak,* and the lower surrounding smoothed and abraded surface, is elsewhere repeated in granite country as—to mention only two examples—in the little knob at 6,800 feet at the south-west end of Kangaroo Ridge and at Alpine View (*ca.* 5,530 feet) at the north-eastern end of Ramshead Range; these we regard as possible *nunatakr.* Since our last paper was written we have found an interesting piece of probably corroborative evidence of ice-cap glaciation in the shape of distinct glacial groovings or flutings on a curving, subvertical face of granite near the Summit road some 300 yards past Perisher Gap and at approximately 6,000 feet A.S.L., on the southern flank of The Perisher. The markings dip steeply south-east approximately, the direction of movement postulated for the ice-cap hereabouts. Possibly the glaciated rock-face had been buried under glacial or other deposits until comparatively recently, and was only revealed by removal of the overburden. The discovery encourages hopes that close examination in likely situations will disclose further similar evidences of glaciation.

In a previous paper (Browne *et al.,* 1944) it was reported that Macdonalds Creek, a tributary of the Upper Burrungubugge River rising in the Main Divide, contained a profusion of rounded boulders, some of them quartzite. Subsequent mapping by the Geological Survey of New South Wales (Hall, 1955; Hall and Lloyd, 1954) confirmed this finding and showed that the narrow belt of Ordovician quartzite and slate running north-north-east on the western side of the Main Divide—the obvious source of the boulders—lies entirely outside the drainage-basin of Macdonalds Creek. Some agency other than water or valley-ice was, therefore, responsible for the original transport, and an ice-cap glacier seems the most likely. Quartzite has also been found among the boulder-accumulations in the wide swampy valley descending from Brassy Gap on the left bank of the Burrungubugge.

Reference is made above to the possibility that the moraine material on the south-east side of Ramshead Range is attributable to ice-cap lobes spilling over the edge of the plateau into the Crackenback valley.

At the south-west end of the range, immediately south-west of North Ramshead Peak, is a somewhat flat, cirquoid hollow, at least ½-mile long in an east-west direction and ¼-mile wide, separated by a low, narrow col from a rather flat hanging tributary of Cootapatamba Creek. It has walls up to 250 feet high and its floor, at a little over 6,850 feet A.S.L., is littered with moraine blocks which increase markedly in abundance just before the creek draining it begins to descend eastwards through a narrow exit largely filled with great granite blocks. A rapid descent, during which the main creek is joined by a branch draining an adjacent hollow, leads down to another cirque-like hollow at 6,400 feet. From the north this receives a short, scoop-shaped or shallow cirquoid valley with a western wall of 400 feet, heading in a double col that separates it from the Etheridge Range cirques and the Snowy headwaters; near the head of this valley is a small cross-moraine. The main valley now begins a steep descent to the Crackenback more than 1,900 feet below, and it is impossible to tell for what distance the ice occupied it before rejuvenation occurred.

The most southerly tributary of Merritts Creek rises in a flat col at 6,410 feet; this has a very gentle southerly slope for ½-mile before steepening. Erratics of white granite have been traced from the north to the col (1963) and down on the southern side, and it is certain that the ice-cap here spilt over into the Crackenback valley.

It is impossible to say definitely whether the moraine on the Crackenback valley side below the cols at the heads of Spencers Creek tributaries originated from the ice-cap or whether they belonged to an earlier phase of the valley-glaciation, when the surface of the glacier occupying Upper Spencers valley was at 6,200 feet or more and the ice might have spread east as far as the cols in the watershed; but the boulder accumulations visible from The Porcupines Ridge are more likely to have come from ice-cap lobes, and the same is probably true of those farther to the north-east; indeed, there may have been, along the edge of the range as far as Thompsons Plain and Pretty Point, a series of lobes or tongues projecting from the various cols and forming little hanging glaciers high above the Crackenback, whose valley-floor was well below the limit of glaciation.

From the flat saddle at 5,385 feet immediately south of Alpine View, ice seems to have spilt over down a little valley, now choked with boulders, on to the south part of Boggy Plain, where it was joined from the west by a tongue or lobe coming over Rennix Gap, and spread across Boggy Plain (*ca.* 5,200 feet) leaving a train of boulders up to 10 or 15 feet long, passed through a col on its eastern margin and made its way down a tributary of Splitters Hut Creek. A little farther north another tongue moved down a tributary of Brooks Mill Creek to about 4,800 feet A.S.L., where terminal moraine material includes diorite as well as granite boulders from a higher level. Indeed, the eastern margin of Boggy Plain and the rather steep slopes below it, down to a flattish step about 4,800 feet, are strewn with what are thought to be glacial erratic boulders. From the north end of the plain yet another tongue, perhaps reinforced by a little glacier from the north, descended along the headwater valley of Sawpit Creek and may have reached the flat stretch known as Wilson Valley at 4,800 feet, to judge by the litter of boulders, either glacial or fluvioglacial, along the creek-bed.

Though no exact boundaries can be drawn, a survey of the evidences noted in our own and previous papers (e.g. David *et al.*, 1901; David, 1908) suggests that an ice-cap glaciation affected all the high country of the Kosciusko plateau from Cascade Creek to Mt. Jagungal, through Mt. Kosciusko and the high country north and north-west of it, through the Mt. Tate country to Gungartan (on whose western slopes erratics were found) and Disappointment Spur; The Kerries and The Brassy Range; the country between the Snowy and the Summit road including Perisher Range and The Plains of Heaven; Ramshead Range from the southern head of Merritts Creek through the Kangaroo ridge and Mt. Wheatley to Alpine View and Rennix Gap; and the Crackenback plateau south-west of Little Thredbo River. The ice-cap also sent lobes over the Ramshead Range to form little hanging glaciers on the left bank of the Crackenback valley.

## Cols

In a previous paper (1957) we expressed the view that the cols or saddles so common in the area are of pre-glacial origin but were traversed and modified by glaciers. For some cols, however, there seems to be no fluvial explanation, for there are no streams heading in them. They are usually flat and shallow, cut directly across the ridge separating two parallel valleys, and may have been diffluent passes eroded out by either ice-cap or valley glaciers. Examples are to be seen on the meridional ridge between Amos and Taylor creeks; between the east and west branches of Farm Creek opposite to where the latter is joined by the creek draining Perisher col; on the right bank of Wrights Creek where it bends sharply left to make for Upper Spencers Creek; on the north-eastern extension of Mt. Wheatley ridge near Perisher Village, and elsewhere.

Possibly related to the ice-cap are the cols immediately east of Mt. Townsend and on the smoothed granite ridge running north from it; of the same general type are the cols in the flat immediately south-west of the main head of Trapyard Creek.

## Age of the Glaciations

The age of the first or ice-cap glaciation is not known. It seems that, after its disappearance and before the onset of the valley-glaciation, the valley of the Snowy River downstream of Charlottes Pass was deepened by some 400–500 feet, and that the excavation of other valleys, such as that of Rawson Creek, belongs to the same interval, which may, therefore, have been quite considerable. Costin *et al.* (1967) have noted that in the "slate" country about Northcote Peak and Carruthers Peak frost-weathering has penetrated to a much greater depth (15 feet) below the surface than it can do under existing climatic conditions; not improbably the deep penetration occurred mainly after the glacial smoothing of the surface and before the onset of the valley-glaciation. Unfortunately, there seems to have been no investigation of the extent of frost-shattering beneath the floors of the glaciated valleys, which might have yielded interesting comparative data.

We have already (1963) stated our belief, based on the state of preservation of the respective moraines and on the transgression of cirque-moraines on areas already eroded by valley-glaciers, that the third or cirque glaciation took place at a substantial time after the valley-glaciation; this seems to have been the last manifestation of truly glacial activity in the area. There are, it is true, at the higher altitudes (*ca.* 6,400 feet and over) nivation hollows which are apparently still in process of growth, and it is possible that some of them were initiated during the cirque-glaciation. All these suggestions, of course, in the nature of the case, can only be tentative.

On general grounds the Kosciusko glaciation is usually assigned to the Pleistocene. David's (1901, 1908) estimates for some of the events in it were admittedly based on inexact data; the scanty $^{14}C$ datings available do not carry the matter very much farther. Peat from the filling of a lake depression in Perisher valley yielded a date of 8100 ± 250 B.P. and two samples of peat from the little Club Lake cirque 4580 ± 220 and 4400 ± 90 B.P. respectively;* the first deposits are younger than the valley-glaciation and the other two post-date the cirque-glaciation, but by how much, of course, we do not know. Costin *et al.* (1967) refer to "the last glaciation of the Kosciusko area approximately 15–20,000 years ago" on the basis of datings of valley-peats, but from the context it is not clear whether the second or the third glaciation is meant; they also state: "The area has been glaciated at least once (approximately 15,000 years ago) and possibly again more recently". Elsewhere Costin (1967, p. 63) has stated a trifle more positively: "Glaciers were active 20,000 years ago and probably more recently". Particulars of the evidence will be awaited with interest.

More recently Costin and Polach (1969) have determined that buried soils from Munyang and Geehi containing woody fragments are *ca.* 31,000 years old. The exact significance of this finding is not clear. The date corresponds roughly to part of an interstadial in the Würm of Europe, and may indicate a mild interval between two of the Kosciusko glaciations, rather than the periglacial conditions suggested by the authors.

*References*


BROWNE, W. R., 1967.—Geomorphology of the Kosciusko Block and its North and South Extensions. PROC. LINN. SOC. N.S.W., 92: 117–144.

BROWNE, W. R., and VALLANCE, T. G., 1957.—Notes on Some Evidences of Glaciation in the Kosciusko Region. PROC. LINN. SOC. N.S.W., 82: 125–143.

————, and ————, 1963.—Further Notes on Glaciation in the Kosciusko Region. PROC. LINN. SOC. N.S.W., 88: 112–129.

————, DULHUNTY, J. A., and MAZE, W. H., 1944.—Notes on the Geology, Physiography and Glaciology of the Kosciusko Area and the Country North of it. PROC. LINN. SOC. N.S.W., 69: 238–252.

————, VALLANCE, T. G., and RUTLEDGE, H., 1956.—Some Examples of Stream-Derangement in the Kosciusko Area. PROC. LINN. SOC. N.S.W., 80: 267–273.

COSTIN, A. B., 1967.—Alpine Ecosystems of the Australasian Region. Arctic and Alpine Environments (Eds. H. F. Wright, Jnr., and W. H. Osborn). Indiana Univ. Press. pp. 55–87.

————, and POLACH, H. A., 1969.—Dating Soil Organic Matter. "Atomic Energy in Australia". C.S.I.R.O. Pubn. 12 (4): 13–17.

————, THOM, B. G., WIMBUSH, D. J., and STUVIER, M., 1967.—Non-sorted Steps in the Mt. Kosciusko Area. *Bull. Geol. Soc. Amer.*, 75: 979–992.

DAVID, T. W. E., HELMS, R., and PITTMAN, E. F., 1901.—Geological Notes on Kosciusko with Special Reference to Evidences of Glacial Action. PROC. LINN. SOC. N.S.W., 26: 26–74.

DAVID, T. W. E., 1908.—Geological Notes on Kosciusko. Pt. 2. PROC. LINN. SOC. N.S.W., 33: 657–668.

HALL, L. R., 1955.—Geology of Snowy Mts. Area, No. 2, Gungarlin-Burrungubugge Rivers. Ann. Rept. Dept. of Mines, N.S.W., for 1951: 76–77.

————, and LLOYD, J. C., 1954.—Geology of Snowy Mts. Area, No. 1, Toolong: and Map. Ann. Rept. Dept. of Mines, N.S.W., for 1950: 96–104.

MOYE, D. G., 1955.—Engineering Geology for the Snowy Mts. Scheme. *Journ. Inst. Eng. Aust.*, 27 (10–11): 287–298.

RAY, L. L., 1949.—Alpine Glaciation. *Bull. Geol. Soc. Amer.*, 60: 1475–1484.

RITCHIE, A. S., 1953.—A Contribution to the Geology and Glaciology of the Snowy Mts. *Jour. Proc. Roy. Soc. N.S.W.*, 86: 88–93.

VALLANCE, T. G., 1954.—The Occurrence of Varved Clays in the Kosciusko District. PROC. LINN. SOC. N.S.W., 88: 221–225.


* *Radiocarbon*, 1960, 2, 175-186, and 1962, 5, 152.